Two Hundred Sixty Pediatric Emergency Airway Encounters by Air Transport Personnel


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Background: Effective airway management is the cornerstone of resuscitative efforts for any critically ill or injured patient. The role and safety of pediatric prehospital intubation is controversial, particularly after prior research has shown varying degrees of intubation success. We report a series of consecutive prehospital pediatric intubations performed by air-transport providers.

Methods: We retrospectively reviewed intubation flight records from an 89-rotorcraft, multistate emergency flight service during the time period from January 1, 2007, to December 31, 2009. All patients younger than 15 years were included in our analysis. We characterized patient, flight, and operator demographics; intubation methods; success rates; rescue techniques; and adverse events with descriptive statistics. We report proportions with 95% confidence intervals and differences between groups with Fisher exact and χ² tests; P < 0.05 was considered significant.

Results: Two hundred sixty pediatric intubations were performed consisting of 88 medical (33.8%) and 172 trauma (66.2%) cases; 98.8% (n = 257) underwent an orotracheal intubation attempt as the first method. First-pass intubation success was 78.6% (n = 202), and intubation was ultimately successful in 95.7% (n = 246) of cases. Medical and trauma intubations had similar success rates (98% vs 95%, Fisher exact test P = 0.3412). There was no difference in intubation success between age groups (χ² = 0.26, P = 0.88). Three patients were managed primarily with an extraglottic device. Rescue techniques were used in 11 encounters (4.2%), all of which were successful. Cricothyrotomy was performed twice, both successful.

Conclusions: Prehospital pediatric intubation performed by air-transport providers, using rapid sequence intubation protocols, is highly successful. This effect on patient outcome requires further study.

Key Words: prehospital, helicopter, intubation

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Out-of-hospital tracheal intubation is an accepted practice; however, there is wide variability in tracheal intubation performance by prehospital personnel. Prior research on paramedic intubation performance and patient outcomes after prehospital intubation has yielded mixed results.1-6 Study in pediatric populations has demonstrated similar findings.7-9 In addition, some evidence suggests prehospital use of bag-valve-mask ventilation may be equivalent to endotracheal intubation for hypoxic and hypopneic children.9 Given this, some agencies are no longer including pediatric tracheal intubation as part of a prehospital airway protocol. Difficulties with pediatric prehospital intubations can stem from low intubation volume, environmental constraints, anatomical variations with age, and inadequate training. Adult intubation performance and patient outcomes for helicopter emergency medical services (EMS) providers have shown better results and improved survival compared with ground personnel.6,10 Pediatric prehospital intubation in this select group of providers, however, has been underreported. We report a consecutive series of pediatric intubations performed within an 89-rotorcraft, multistate transport system (Air-Evac EMS, Ltd) to characterize methods, success rates, and rescue techniques when intubation is performed by flight paramedics and nurses, using rapid sequence intubation (RSI) airway management protocols.

METHODS

Study Design

This is a retrospective analysis of consecutive intubations performed by flight paramedics and nurses. Institutional review board approval was obtained both at the University of Illinois–Peoria and at Brigham and Women’s Hospital (Harvard Medical School) before analysis. Data analysis followed conventions established for the National Emergency Airway Registry.

Setting

Intubations were performed by personnel from a large air-medical transport company (Air-Evac EMS), based in West Plains, Mo. At the time of data collection, the company operated 89 long-range (206L) helicopters out of 85 air-medical bases throughout the central part of the United States (Fig. 1). Air-Evac transports to more than 1000 hospitals and records an average of 26,000 flights per year including both interfacility transfers and on-scene flights. Most crews operate from stations in rural settings and are not based out of urban or academic medical centers. All providers underwent quarterly training consisting of seminars on airway assessment, difficult airway management, and RSI under the instruction of regional medical directors. In addition, case-based skills sessions, utilizing neonatal and pediatric METI ECS simulators, were required that focused on intubation technique and difficult airway management. In addition, extraglottic device (EGD) and needle cricothyrotomy techniques were practiced every 3 months. Paramedics and flight nurses had an average of 12 years of experience and performed more than 25 airway procedures.
annually through a combination of field and simulated intubations. Pediatric airway management was guided by standard intubation protocols that were reviewed and approved annually, by the senior medical director. Indications for prehospital pediatric intubation included oxygenation or ventilation failure, inadequate airway protection, and predicted airway deterioration before or during transport. Protocols outlined the use of pretreatment drugs, induction agents, and neuromuscular blockers for RSI, sedation-facilitated intubation, and algorithms for crash and failed airway management. Accepted weight-based drug doses were used during airway management.

Selection of Participants
All pediatric patients younger than 15 years who underwent at least 1 airway maneuver from January 1, 2007, to December 31, 2009, were included in our analysis.

Methods of Measurement
Each encounter was categorized as either a medical or trauma intubation based on the clinical and scene information. After an assessment by flight personnel and indications for intubation were met, standard airway management protocols were followed. A difficult airway assessment was done, whenever possible, by each operator before administration of medication, and if appropriate for neuromuscular blockers, RSI was performed. The operator evaluated mouth opening, cervical spine mobility, mandible and tongue size, and location of the thyroid cartilage before airway intervention. This approach has been used successfully to predict difficult direct laryngoscopy in emergency department patients. Otorrhageal RSI was performed by direct laryngoscopy if the airway was not predicted to be difficult. An EGD (Combitube, Coviden, Mansfield, MA, laryngeal mask airway [LMA], or laryngeal tube) was used as the initial airway maneuver if the patient was thought to be too difficult to safely receive neuromuscular blockade. Extraglottic devices placed as the first planned method of airway control occurred with sedation only. Rare, in-flight cardiopulmonary arrests with a crash airway were managed with immediate direct laryngoscopy, without RSI medications, followed by EGD placement if laryngoscopy failed. A failed airway was defined in 2 ways: a failed intubation attempt in combination with persistent hypoxia (oxygen saturation <90%) despite maximal supplemental oxygen and assisted ventilations or 3 failed intubation attempts by the flight nurse or paramedic.

Failed airways were managed with either an EGD (LMA, laryngeal tube, or Combitube), continued bag-mask ventilation, or surgical airway if the patient could not be intubated or ventilated by other means. Malleable stylets were used routinely. Video laryngoscopes were not available. The operator completed a contemporaneous electronic flight record and standardized intubation report following each intubation. Procedural entries for intubation had a demand function on the electronic flight record and could not be skipped. Recorded variables included patient age, sex, estimated weight, flight classification, protocol and drugs used, initial airway management maneuver, number of intubation attempts, intubation success, and use of rescue devices. An intubation attempt was defined as insertion of any laryngoscope blade with passage of an endotracheal tube beyond the patient’s lips.
Confirmation of endotracheal tube placement was done by auscultation and colorimetric end-tidal CO₂ detection. Successful endotracheal intubation was defined by tube passage, resulting in chest rise and color change on a qualitative end-tidal CO₂ detector. Vital signs were noted to be “stable” or “unstable” both before and after intubation, but specific values were not recorded in the registry. Intubation reports were monitored for completeness by each regional medical director with a reporting compliance of 100%.

Data Collection and Processing
During or immediately after each flight, operators recorded all intubation details onto a structured data form. Data were reviewed for completeness and entered by the medical director and nurse educator into the company’s main database (SQL database; Microsoft Access, Redmond, Wash). Data were then imported into a spreadsheet (Microsoft Excel, Redmond, Wash) for analysis. Structured queries were performed to retrieve relevant data with regard to intubation method, success, attempts, rescue techniques, and the use of surgical airways.

Primary Data Analysis
We present descriptive data and Fisher exact and χ² tests for binary comparisons, with \( P < 0.05 \) considered significant. We performed all analyses with SAS 9.12 (SAS Institute, Cary, NC).

RESULTS
During the 3-year study period, 4871 intubations were performed within the Air-Evac system including 260 pediatric intubations. Of pediatric intubations, 88 (33.8%) were performed for medical indications, and 172 (66.2%) were for trauma. The most common indications for pediatric intubation were head injury \( (n = 64) \) and seizure \( (n = 26) \), respectively. The mean patient age was 7.33 years. One hundred three \( (39.6\%) \) were female, and 157 \( (60.4\%) \) were male.

Figure 2 depicts methods chosen, failed intubation encounters, and the rescue methods used; 98.8\% \( (n = 257) \) of the 260 patients underwent an orotracheal intubation attempt as the first method, all using RSI. Intubation was successful on first attempt 78.6\% \( (n = 202) \) of the time and was ultimately successful in 95.7\% \( (n = 246) \) of patients. Of successful intubations, 95.9\% \( (n = 236) \) were completed in 2 or fewer attempts (Fig. 3). There was no difference in intubation success between medical and trauma patients \( (98\% \text{ vs } 95\%, \text{ Fisher exact test } P = 0.3412) \). In addition, there was no difference in intubation success between patients in age groups 0 to 2, 3 to 7, and 8 to 14 years \( (\chi^2 = 0.26, \text{ } P = 0.88) \). Age-stratified success rates are presented in Table 1. Three patients \( (1.1\%) \) were managed primarily with an EGD as the first method chosen without an antecedent intubation attempt; all were successfully

![FIGURE 2. Breakdown of airway management encounters.](image)

![FIGURE 3. Success rate per attempt number.](image)
TABLE 1. Success by Age Group

<table>
<thead>
<tr>
<th>Age</th>
<th>Success</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2 y</td>
<td>Yes 53</td>
<td>55</td>
</tr>
<tr>
<td>3–7 y</td>
<td>Yes 78</td>
<td>81</td>
</tr>
<tr>
<td>8–14 y</td>
<td>Yes 115</td>
<td>121</td>
</tr>
<tr>
<td>Total</td>
<td>246</td>
<td>257</td>
</tr>
</tbody>
</table>

Oxygenated. Eleven patients were not successfully intubated. Of these, 7 were successfully managed with an LMA and 2 with a Combitube. Rescue cricothyrotomy was performed in 2 patients, aged 2 (needle cricothyrotomy) and 14 years (open [surgical] cricothyrotomy). Both were successful. There were no reports of a patient death due to a failed airway.

**DISCUSSION**

Out-of-hospital airway management remains a necessary lifesaving procedure for critically ill and injured children, yet heterogeneous results regarding prehospital intubations, the feasibility of prolonged bag-and-mask ventilation in lieu of tracheal intubation leave the extent of prehospital pediatric airway management up for debate. Tracheal intubation is a high-risk procedure that requires specialized training, practice, knowledge of airway anatomy, human physiology, pharmacology, and plans for rescue should intubation fail. Even garden-variety intubations represent a high-risk situation for every patient, especially when neuromuscular blockade is used. Air-medical teams often take care of the most severely compromised pediatric patients for whom expert airway management may have a direct impact on outcome. For our group of operators, prehospital pediatric airway management is most often accomplished with tracheal intubation by direct laryngoscopy using RSI, showing acceptable first-pass success rates and high ultimate success rates. Air-medical intubation success rates in studies including both adult and pediatric patients, using RSI protocols, have demonstrated intubation success rates as high as 95%. Our study showing 95.7% success confirms these findings and suggests it extends to pediatric populations. Performance may be typical of other air-medical programs with similar operator characteristics.

Significant anatomic differences exists among patients younger than 3 years. This can make intubation more challenging for neonates and very young children. Subgroup analysis of children aged 0 to 2, 3 to 7, and 8 to 14 years showed similar intubation success rates. Although our number of failed intubations is small, rescue methods, including placement of EGDs and surgical airway techniques, were successful 100% of the time.

Early investigations of out-of-hospital pediatric intubation success by ground providers have shown varying results, but as many as 43% of prehospital intubations may be unsuccessful. This inconsistency has many contributing factors but has been linked, in part, to minimal airway management requirements for paramedic certification and skill degradation because of infrequent field intubations. Procedural accomplishment is associated with repetition, and paramedics in high-volume settings or those with greater access to simulation or operating room experience have shown higher rates of intubation success. The baseline skill set of intubators in our study was high. Air-Evac provides an extensive airway training program for new employees and maintains skills through regular training sessions, all with strict oversight by regional medical directors. In our study group, the average paramedic and flight nurse had more airway management experience than what is typically seen for ground paramedics. Like other rarely performed, high-risk procedures, experience and simulation training are likely going to play a prominent role in maintaining skills. Our findings suggest that prehospital providers, when provided adequate intubation experience supplemented by simulation training, are highly skilled and successful with emergency airway management in pediatric populations. This has implications for all EMS companies as they evaluate ongoing paramedic education and skills maintenance.

Eleven patients (4.2%) were not intubated and required rescue airway maneuvers. Although this number is small, any failed airway is concerning, given the possibility of prolonged hypoxia. In our study, all patients except 2 had successful rescue with an EGD, most commonly an LMA. Surgical airways were performed successfully on the remaining 2 patients. These findings indicate that backup management plans can be enacted efficiently and successfully in our study group. Introduction of video laryngoscopy for pediatric intubation in this system might further help to reduce the failure rate to zero, the desired level.

**LIMITATIONS**

Our study has some important limitations. First, these intubations were performed by advanced paramedics and flight nurses within a high-volume air-transport company, and our results represent what operators with a similar training and intubation volume might achieve. These results may not be generalizable to traditional paramedics working in other settings or with lower annual intubation volume. Second, self-reported data have intrinsic limitations, and underreporting of poorly performed intubations including those with multiple failed attempts and adverse events is possible. Close compliance monitoring by regional medical directors and mandatory reporting fields for intubation in the electronic flight record limits the possibility of selective reporting. The structured data form was originally designed for internal, administrative purposes and was not created with a developed research protocol in mind. This has introduced nonstandard definitions and variables into our data pool and has limited our ability to perform certain analyses. For future studies, operational definitions can be clarified during prospective collection. First, the definition used for tracheal intubation attempt required insertion of a tracheal tube while the most widely used definition of intubation attempt simply requires insertion of the laryngoscope blade beyond the teeth. Therefore, it is impossible to tell whether the patients we reported as being primarily managed with an EGD as the first airway maneuver actually had a direct laryngoscopic attempt first. This would bias our results toward better first-pass intubation success. However, because that number was small (n = 3), success outcomes would have remained virtually unchanged. In addition, many data points that would have been added and additional level of understanding were not collected. Vital signs surrounding intubation were noted to be “stable” or “not stable,” but specific values were not recorded. We also cannot make comparisons stratified by the medications used. With the exception of pretreatment agents, medications used during intubation were documented in the registry as drug classes instead of specific agents. In other words, if RSI was performed, then succinylcholine or rocuronium could have been used at standard doses and that would have been an acceptable
entry for “paralytic used” without knowing which agent was administered. Finally, prehospital airway studies often use destination tube confirmation as a measure of validating successful tracheal intubation. This was not recorded, and therefore an overestimation of intubation success within our sample is possible. All tubes, however, were verified with end-tidal CO₂ detection, in addition to auscultation and observation of chest rise. In addition, waveform capnography was a routine part of the postintubation care during transport, making the chance of an unrecognized misplaced tube very low. There were no reports of patient death due to a failed airway. Patients intubated by Air-Evac personnel but not flown because of instability or ongoing cardiopulmonary resuscitation in the field were not included in our analysis because a transport flight record was not generated for these encounters. Certainly, this population had poor outcomes, and some may have died as a result of failed airway management. Although this is possible, the likelihood that this number is large enough to have a meaningful impact on overall success is small. Nevertheless, this biases our findings toward better performance.

This group of advanced-level providers underwent advanced simulation airway training multiple times per year as part of routine competency checks, and the effect this extra training has on final performance above that obtained from real-life experience is difficult to gauge. Finally, patients were not followed longitudinally in the hospital, and final functional or survival outcomes were not recorded. How our results translate to patient survival and neurologic function requires further study.

CONCLUSIONS

In this high-volume air-transport agency, skilled prehospital providers, using RSI protocols, exhibited high pediatric intubation success rates, modest first-pass success rates, and successful application of rescue methods including use of EGDS and surgical techniques. These data may be used to better define performance standards for air-medical providers performing pediatric tracheal intubation.

REFERENCES


